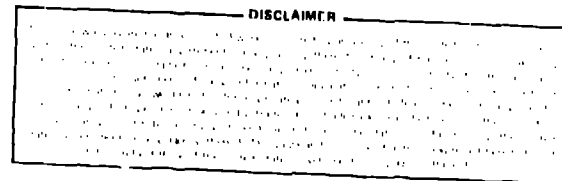


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GENERALIZED ULTRASONIC SYSTEM FOR MICROCOMPUTER CONTROLLED DATA COLLECTION

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ABSTRACT

A system developed by the NDE Group of the Los Alamos Scientific Laboratory for the automated scanning of objects with an axis of rotation is described. This system is still being expanded to allow greater versatility in the motions. Data which was collected using the system and some typical test objects are also presented and discussed.

INTRODUCTION

In order to provide adequate ultrasonic inspection of parts used or fabricated within the Los Alamos Scientific Laboratory (LASL), it became apparent that a specialized scanning system was necessary to position the transducer relative to the parts and move the parts. Many of the typical parts which are inspected have spherical geometry. Two half shells are usually brazed or welded together to form the sphere. A scanner was designed and fabricated which could scan the surface of a spherical object of virtually any size to a maximum diameter of 225 mm. This scanner is shown in fig. 1. The size variation was partially accommodated through the use of pedestals of different heights. Initially the scanner was continuously driven and the results were plotted using a slaved X-Y recorder. The X- and Y-positions were generated using a sin-cos potentiometer. This caused the recorder to draw a circle as the turntable moved. The radius of this circle was controlled by a potentiometer which was coupled to the worm gear shaft which positions the swing arm. The diameter of the circle is therefore a function of the position of the transducer relative to the equator of the sphere. A relatively simple two angle manipulator, which we had designed and used previously in manual scanners, was mounted on the swing arm to permit aiming of the transducer. The go/no-go output of the flaw gate or the ultrasonic instrument controlled the pen lift mechanism of the recorder.

This scanner worked well. With the availability of microcomputer hardware and software, the equipment was upgraded to allow simple control of the data collection process by the microcomputer. A photosensor was used to indicate the "0" position of the turntable. The amplitude voltage from the gate analog output was fed to an analog-digital converter (ADC). Samples were taken at programmed time increments after the "0" position was passed. The digitized amplitude data were stored in arrays sequentially, so that the location of the datum is representative of part rotation or longitude. Each array represented one complete rotation at a particular latitude. An array length of 1000 words was chosen, which

resulted in samples being taken at 0.36° increments.



Fig. 1 Original object scanner.

Many of the inspections are made on equatorial welds in vessels which have a square butt joint configuration at the weld root. The welds frequently are also allowed to have a finite depth of incomplete penetration. This required us to make a quantitative determination of the penetration depth. The measurement of the raw reflection signal did not yield a direct indication of the root height due to saturation of the signal at a notch depth of about 0.5 mm or about 20% of the wall thickness. Greater depths than that do result in the reflection being observed at a greater number of latitudes when the object was scanned. At this point it was decided that it would be advantageous to have the two scanner motions driven under software control using stepper motors.

SYSTEM DESCRIPTION

A duplicate of the original scanner was fabricated with modifications allowing the installation of stepper motors. The scanner is used as part of an integrated system containing a microprocessor for control. Fig. 2 shows the components of the entire system. The scanner is shown in figure 3. Gear reduction drives are utilized to increase the torque output of the motors and to decrease the relative movement of the driven axis to a reasonable value. A 30 to 1 reduction on the vertical axis rotation is used resulting in a incremental movement of 0.12° per step. For the swing arm a 20 to 1 reduction was used which results in a incremental movement of 0.003° per step. The particular motor driver which we are using drives the motors at 100 increments per revolution. The motors operate at 200 steps per revolution but the drive controller outputs two steps per command increment. Both motors are operated within the zero error start/stop speed regime or at about 250 steps per second. Backlash within the scanning motions is reduced or, for our purposes, eliminated by only scanning in one direction. When a particular motion is returned to a starting position, it is moved past the desired start and then repositioned by moving to that position in the same direction as scanning is done. This is a standard method for backlash compensation in numerical control machines.

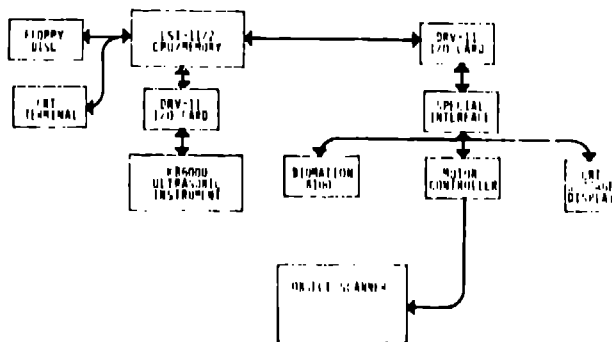


Fig. 2 Block diagram of data collection system.

An additional axis has also been added to the tank portion to allow transverse movement of the transducer assembly. This axis is assembled as a frame so it can be removed when not required. Figure 4 shows the tank with the frame attached. This axis is used when two transducers are required to perform the inspection or experiment. The axis has an incremental movement of 0.01125 mm. per step.

The particular motor controller being used was built by Group M-5 of LASL. It is capable of decoding an instruction from the computer interface to drive one of four motors in a specified direction for a directed number of steps from 1 to 255. Only one axis can be driven at a time, but this is normally not a significant problem. Driver or translator cards built at LASL are also used in

the controller. The controller is addressed and coupled to a single interface with a Bionation 3100 transient recorder and a M-5 designed storage display controller.

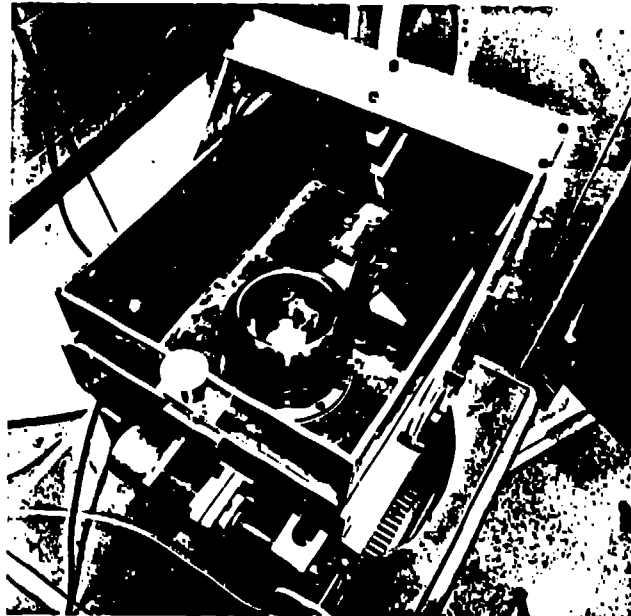


Fig. 3 Scanner driven by stepper motors.

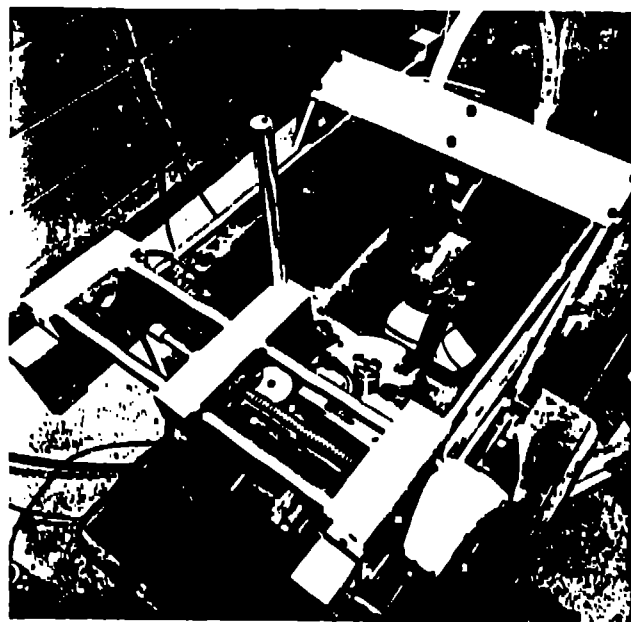


Fig. 4 Transverse motion axis frame mounted on tank assembly.

The microcomputer system that is being utilized is a DEC 11/2 processor with 32k words of memory and the extended and floating point instruction set options. The RT-11 operating system is used. A dual-drive double-density floppy disc unit is used for program and mass storage. DRV-11 parallel interfaces are used to interface with the external devices. FORTRAN is used as the

high level language and the MACRO assembly language is used to program the operation of the peripheral instruments.

DATA COLLECTION EXAMPLES

As stated previously many of the inspections performed using this system are of equatorial welds. The system is set up by adjusting the swing arm frame height until the change or runout in the water path is minimal when the arm is rotated. This positions the arm pivot axis so that it passes through the center of the sphere. Since a shear wave angle beam inspection is desired, the transducer manipulator is adjusted so that the beam is normal to the surface. An offset angle then is turned into the manipulator to give a nominal 45° shear beam angle. A 5.0 Mhz focused broadband transducer (Aerotech Alpha or Panametrics VIP Series) is used. The focusing improves the spatial resolution along the weld length and the material thickness is thin enough that unsymmetrical focusing due to the spherical surface does not cause problems. The swing arm is moved so that the beam is out of the weld area, and the scanning process begins. The current program makes twenty rotational scans with the arm being incremented 0.3° per revolution. This is normally sufficient to completely traverse the weld zone on the first bounce. A KBI KB6000 ultrasonic instrument is used. This instrument has a digital output of both gate time and amplitude. At the present time only the amplitude word is used. As the scanning process progresses the data are stored in a two dimensional array. An array of the maximum amplitudes observed at each longitude is also maintained. The maximum amplitude array and a polar plot of any data which exceeds 50% full scale amplitude is displayed on a storage scope along with the current amplitude data. This allows the operator to follow the inspection and to make judgements about the validity of the data. When the scanning is completed, the accumulated data plus some title information is stored on floppy disc for further processing.

The stored data is plotted out using a DEC PDP-11/40 on a Versatec printer/plotter without extensive processing. One output is the maximum amplitude values and a polar plot of all points which are greater than 20% of full scale amplitude. The dot size of the latter plot is varied with the amplitude. These plots are shown in Fig. 5. A second output is an isometric representation of the amplitude data for all scans. This plot is shown in Fig. 6. One of the benefits of having the maximum amplitude plot generated by evaluating the data from all scans is that the alignment of the equatorial plane of the test item does not have to be aligned perfectly normal to the rotational axis. Also the notches in the sample or standard do not have to be in perfect alignment, but some tolerance is allowed in their placement.

A second type of evaluation that can be made is studying the refraction and mode conversion of a wave striking a metal disc at varying angles. This geometry is to be used for studying the attenuation in a sample which might contain multiple defects or a zone of modified properties. Fig. 4 shows the basic setup. The longitudinal and shear wave velocities in the disc can be determined.

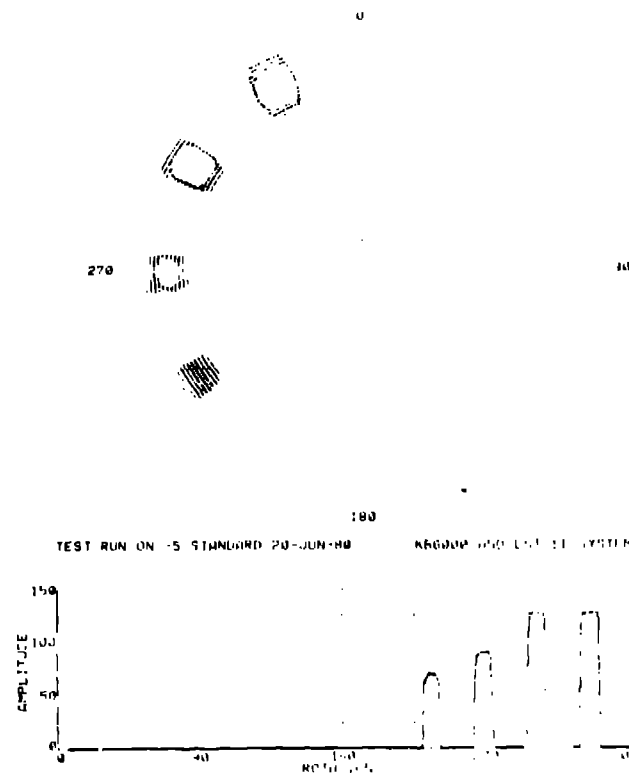


Fig. 5 A graph showing the polar plot and maximum amplitude plot from a standard containing I. D. notches with depths of 5, 10, 20, and 30% of the material thickness.

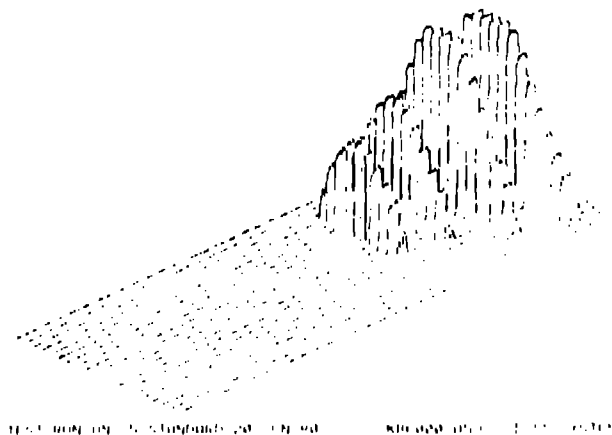


Fig. 6 A graph showing isometric plot representing reflection amplitude for all scans.

Figures 8 through 10 show some of the waveforms obtained from the disc. The wave trains are digitized using a Biomatron 3100 transient recorder. The displayed data is the average of the data from 128 pulses. The longitudinal and shear wave velocities that were calculated from the data are 5917 km/sec and 3330 km/sec. This compares with a longitudinal wave velocity of 5907 km/sec measured using pulsed resonant frequency techniques.

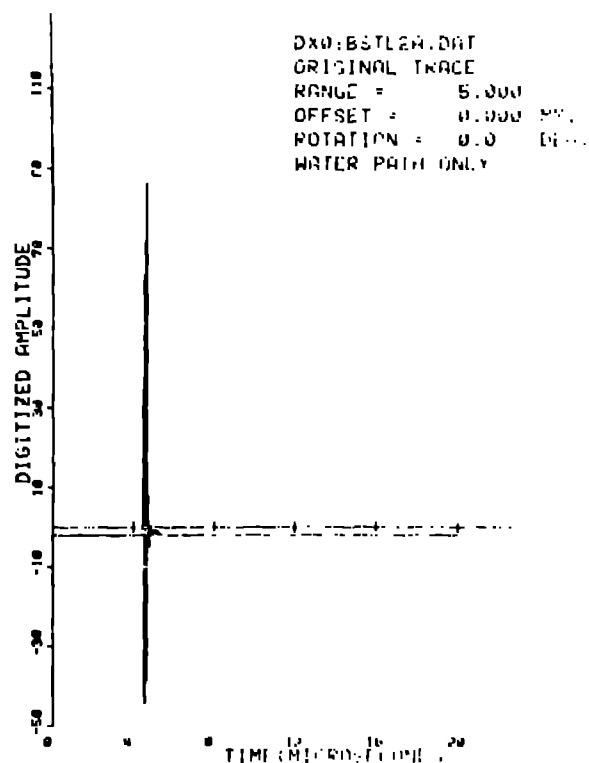


Fig. 7 Wave train obtained without a specimen in the water path.

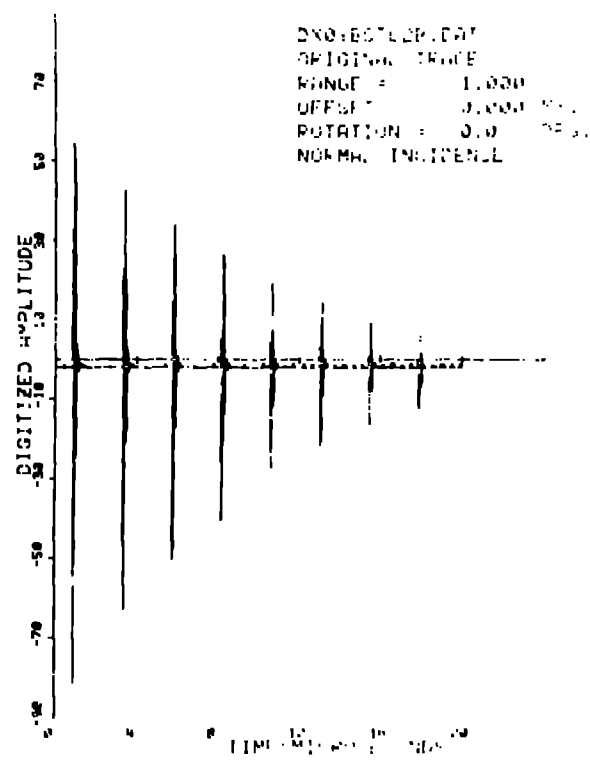


Fig. 8 Wave train obtained with the specimen inserted at normal incidence.

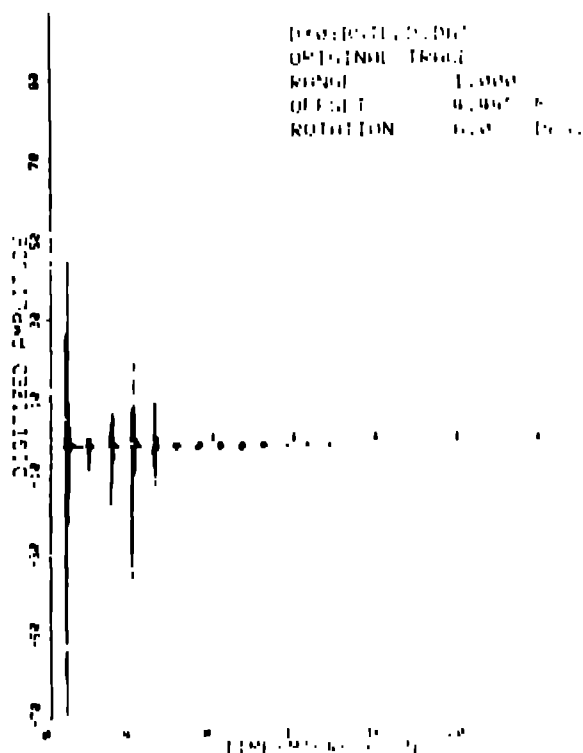


Fig. 9 Wave train obtained with the specimen rotated 6° off normal. The receiving transducer is offset to obtain peak amplitude from the first longitudinal refracted wave.

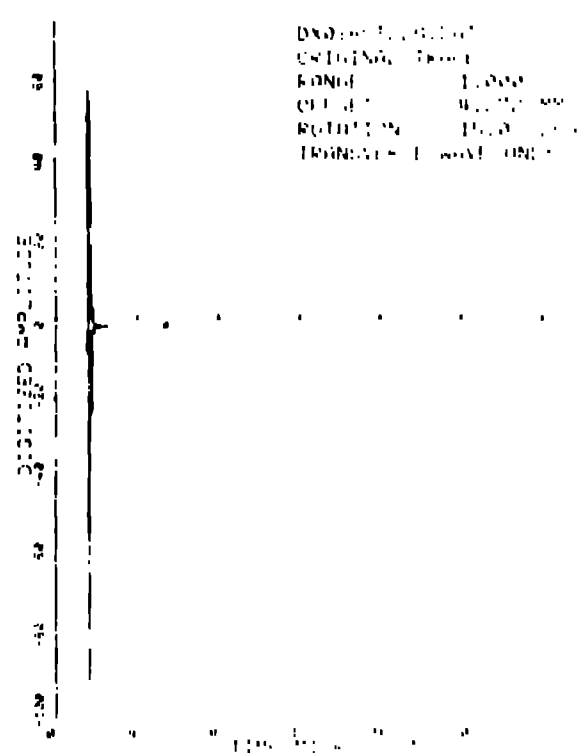


Fig. 10 Wave train obtained with the specimen rotated 15° off normal which is past the longitudinal critical angle. The receiving transducer is offset to obtain peak amplitude from the refracted shear wave.

SUMMARY

Automatic data collection, processing and display using mini- and microcomputer technology has been used by Group M-5 of the Los Alamos Scientific Laboratory to achieve greater detail in ultrasonic inspections. This was achieved by assembling an automated scanner that although it was specifically tailored to spherical shapes can be utilized to perform the sample and transducer motions to take data from virtually any sample which must be rotated on an axis during the inspection or experiment. Work on increasing the types of motion that are available is continuing.

ACKNOWLEDGEMENTS

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I would like to thank E. J. Vonderheide and R. McFarland of Group SD-5 who performed the fabrication of the scanner and attachments with only the aid of cursory sketches. Also H. W. Johnson who did the photography and graphics reproduction.